

CFNS Workshop: Pion and Kaon Structure Functions at the EIC

Tanja Horn (CUA)

Craig Roberts (Nanjing U.)

Overview – Pion and Kaon Structure

- ❑ Protons, neutrons, pions and kaons are the main building blocks of nuclear matter

If we really want to claim we understand hadron structure as relevant for the visible world, we HAVE to understand at least the pion, kaon, proton, neutron (and likely the Lambda) at the same level.

- ❑ Paradoxically, the lightest pseudoscalar mesons appear to be the key to the further understanding of the emergent mass and structure mechanisms.
 - These mesons, namely the pion and kaon, are the Nambu-Goldstone boson modes of QCD.
- ❑ Unravelling their partonic structure and the interplay between emergent and Higgs-boson mass mechanisms is a common goal of three interdependent approaches -- continuum QCD phenomenology, lattice-regularised QCD, and the global analysis of parton distributions -- linked to experimental measurements of hadron structure.

2-5 June 2020

Online

US/Eastern timezone

Remote Workshop 2-5 June, 2020

Overview

[Call for Abstracts](#)

[Timetable](#)

[Contribution List](#)

[Registration](#)

[Participant List](#)

Contact

cfns_contact@stonybrook.edu

The Lagrangian masses of the quarks deliver only $\approx 1\%$ of the proton mass, m_p , and it is the emergence of the bulk of m_p and the (very probably) related mechanism of confinement that are the key unresolved issues in hadron physics. In addressing these issues, the potential of the EIC is enormous. It promises to enable a quantitative understanding of the structure of hadrons, such as the nucleon, pion and kaon, in terms of quarks and gluons, thereby achieving key goals of modern physics. Recent synergistic advances in computation, experiment and theory reveal the prospects for a precise description of the one-dimensional structure of hadrons, exemplified by parton distribution functions (PDFs) and electromagnetic form factors, and of constructing three-dimensional images of hadrons, as expressed in Generalized Parton Distributions (GPDs) and Transverse-Momentum-Dependent Distributions (TMDs). Hence, today, there is an unprecedented opportunity to chart the in-hadron distributions of, *inter alia*, mass, charge, magnetization and angular momentum.

This workshop will canvass recent progress toward a coherent program of pion and kaon structure studies at the Electron-Ion Collider (EIC) that will deliver a new level of understanding of the interplay between experiment and theory. Here, recent progress, including new theoretical insights and rapid computational advances, and the level of phenomenology in the form of global structure studies, and the use of exascale computing are both expected to play a major role.

This workshop aims to capitalize on the success of the EIC, which has led to a [White Paper](#), published in [Eur.Phys.J.A 55](#) (2018), and the EIC documentation, driving toward a significant new edition of the Particle Data Group Handbook, and develop contributions as part of the EIC Handbook.



Starts Jun 2, 2020, 8:00 AM

Ends Jun 5, 2020, 7:00 PM

US/Eastern



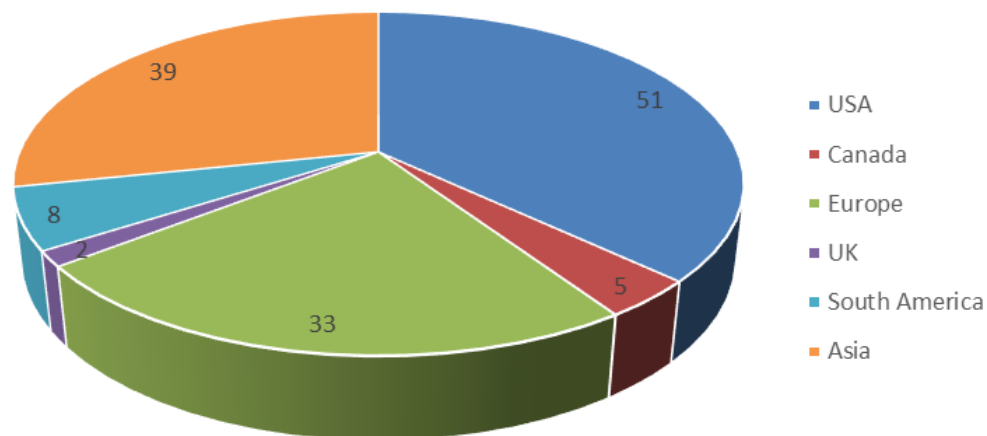
Craig Roberts

Tanja Horn

Large (remote) interest:

- 138 participants registered
- 25% early career researchers
- Attendance: $\sim 100/\text{day}$

Meson Structure Function at the EIC: 138 attendees



Pion and Kaon Structure at the EIC – History

- ❑ PIEIC Workshops hosted at [ANL \(2017\)](#) and [CUA \(2018\)](#)
- ❑ ECT* Workshops: [Emergent Mass and its Consequences \(2018\)](#)

[Mapping Parton Distribution Amplitudes and Functions, \(2018\).](#)

Pion and Kaon Structure at an Electron-Ion Collider

1–2 June 2017, Physics

Jefferson Lab Events - PIEIC2018

Jefferson Lab
EXPLORING THE NATURE OF MATTER

LINKS

- Circular
- Registration
- Program
- Transportation
- Lodging
- Participants List

PIEIC2018

Workshop on Pion and Kaon Structure at an EIC
May 24-25, 2018
The Catholic University of America
Washington, D.C.

Circular

This workshop will explore opportunities provided by the Electron-Ion Collider (EIC) to study the quark and gluon structure of the pion and kaon and will stake stock of the progress since the last workshop at Argonne National Lab: <http://www.pnpi.su.riken.go.jp/~pienka/>

Organizing Committee

Ian Cloet - ANL
Tanja Horn - CUA
Cynthia Keppel - Jlab
Craig Roberts - ANL

Sponsors:

CUA
Jefferson Lab

12000 Jefferson Avenue, Newport News, VA 23606
Phone: (757) 269-7100 Fax: (757) 269-7363

HOME REGISTRATION ACCOMMODATION

Introduction

This workshop at Argonne National Laboratory will explore opportunities provided by the Electron-Ion Collider (EIC) to study the quark and gluon structure of the pion and kaon and will stake stock of the progress since the last workshop at Argonne National Lab: <http://www.pnpi.su.riken.go.jp/~pienka/>

Invited Speakers:

Pion and Kaon Structure at the Electron-Ion Collider

Arlene C. Aguilar,¹ Zafir Ahmed,² Christine Aidala,³ Salma Ali,⁴ Vincent Andrieux,^{5,6} Adnan Bashir,⁷ Vladimir Berdnikov,⁸ Daniele Binosi,⁹ Lei Chang,¹⁰ Chen Chen,¹¹ Pacheo B. C. de Melo,¹² Markus Diehl,¹³ Minghui Ding,¹⁴ Rolf Ent,¹⁵ Gao,¹⁶ Ralf W. Gothe,¹⁷ Mohammad Hattawy,¹⁸ Timothy J. Hobbs,¹⁹ Shaoyang Jia,²⁰ Cynthia Keppel,²¹ Gaëtan Krein,²² Huey-Wen Lin,²³ Rachel Montgomery,²⁴ Hervé Moutarde,²⁵ Pavel Nadolsky,²⁶ Joe Pegg,²⁷ Jen-Chieh Peng,²⁸ Stephane Platchkov,²⁹ Si-Xue Qiu,³⁰ Richards,³¹ Craig D. Roberts,³² Jose Rodriguez-Quintero,³³ Segovia,³⁴ Arun Tadeepalli,³⁵ Richard Thoma,³⁶ University of Campinas - UNICAMP, Instituto de Física de Caracaras, 13506-900, Brazil
²University of Regina, Saskatchewan, S4S 0A2, Canada
³University of Bonn, Institute for Nuclear Physics, 53115, Germany
⁴Catholic University of America, Washington, DC 20064, USA
⁵University of Jyväskylä, Department of Physics, FI-00014, Finland
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Pion and Kaon Structure at an EIC
[Eur. Phys. J. A 55 \(2019\) 10, 190](#)

Workshop on Pion and Kaon Structure Functions at the EIC

Center for Frontiers in Nuclear Science
Workshop series

2-5 June 2020
Online
US Eastern time zone

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Participant List

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chc_contact@stonybrook.edu

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This workshop will canvass recent progress toward a coherent program of pion and kaon structure studies at the Electron-Ion Collider (EIC) that will deliver these maps. Their drawing demands an interplay between experiment and theory. Here, recent experimental developments have been matched by new theoretical insights and rapid computational advances. The progress is completed by high-level phenomenology in the form of global structure function fitting frameworks. Machine learning and exascale computing are both expected to play a material role in this march of progress.

This workshop aims to capitalize on the success of two prior meetings (PIEIC2017, PIEIC2018), which led to a [White Paper](#), published in [Eur. Phys. J. A 55 \(2019\) 10, 190](#). Its near-term goals are to expand this documentation, driving toward a significant new element in the EIC User Group Physics and Detector Handbook, and develop contributions as part of the ongoing Yellow Report Initiative.

Starts Jun 2, 2020, 8:00 AM
Ends Jun 5, 2020, 7:00 PM
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Craig Roberts
Tanja Horn

There are no materials yet.

- ❑ [AMBER/CERN Workshops \(2019+\)](#)
- ❑ [CFNS Workshop \(2020\)](#)
- ❑ [ECT* Workshops \(2021\): Mass in the Standard Model and Consequences of its Emergence](#)

EIC – Meson Structure Questions

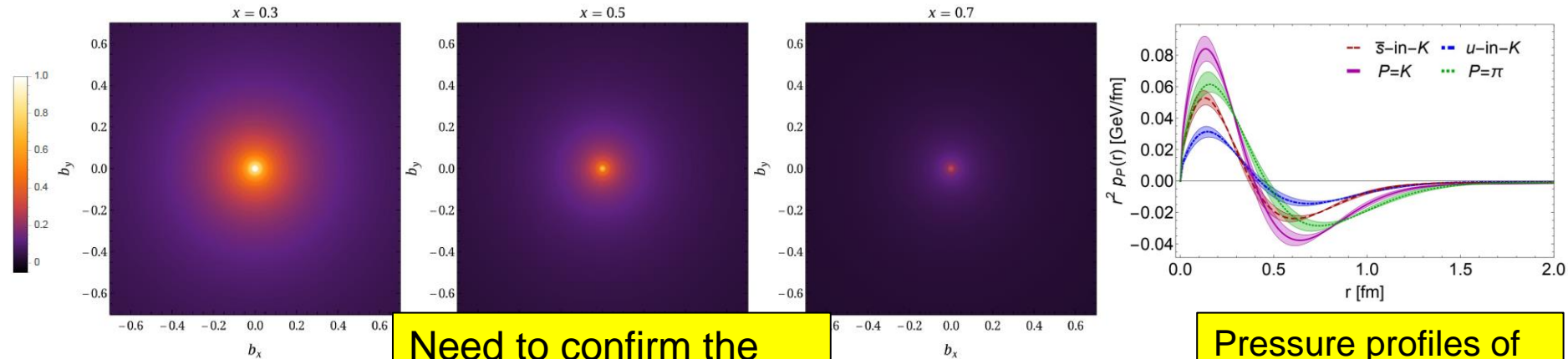
Science Question	Key Measurement[1]	Key Requirements[2]
What are the quark and gluon energy contributions to the pion mass?	Pion structure function data over a range of x and Q^2 .	<ul style="list-style-type: none"> • Need to uniquely determine $e + p \rightarrow e' + X + n$ (low $-t$) • CM energy range ~ 10-100 GeV • Charged and neutral currents desirable
Is the pion full or empty of gluons as viewed at large Q^2 ?	Pion structure function data at large Q^2 .	<ul style="list-style-type: none"> • CM energy ~ 100 GeV • Inclusive and open-charm detection
What are the quark and gluon energy contributions to the kaon mass?	Kaon structure function data over a range of x and Q^2 .	<ul style="list-style-type: none"> • Need to uniquely determine $e + p \rightarrow e' + X + \Lambda/\Sigma^0$ (low $-t$) • CM energy range ~ 10-100 GeV
Are there more or less gluons in kaons than in pions as viewed at large Q^2 ?	Kaon structure function data at large Q^2 .	<ul style="list-style-type: none"> • CM energy ~ 100 GeV • Inclusive and open-charm detection
Can we get quantitative guidance on the emergent pion mass mechanism?	Pion form factor data for $Q^2 = 10$ -40 (GeV/c) 2 .	<ul style="list-style-type: none"> • Need to uniquely determine exclusive process $e + p \rightarrow e' + \pi^+ + n$ (low $-t$) • $e + p$ and $e + D$ at similar energies • CM energy ~ 10-75 GeV
What is the size and range of interference between emergent-mass and the Higgs-mass mechanism?	Kaon form factor data for $Q^2 = 10$ -20 (GeV/c) 2 .	<ul style="list-style-type: none"> • Need to uniquely determine exclusive process $e + p \rightarrow e' + K + \Lambda$ (low $-t$) • L/T separation at CM energy ~ 10-20 GeV • Λ/Σ^0 ratios at CM energy ~ 10-50 GeV
What is the difference between the impacts of emergent- and Higgs-mass mechanisms on light-quark behavior?	Behavior of (valence) up quarks in pion and kaon at large x .	<ul style="list-style-type: none"> • CM energy ~ 20 GeV (lowest CM energy to access large-x region) • Higher CM energy for range in Q^2 desirable
What is the relationship between dynamically chiral symmetry breaking and confinement?	Transverse-momentum dependent Fragmentation Functions of quarks into pions and kaons.	<ul style="list-style-type: none"> • Collider kinematics desirable (as compared to fixed-target kinematics) • CM energy range ~ 20-140 GeV

EIC – Meson Structure Questions

Science Question

Key Measurement[1]

Key Requirements[2]



Need to confirm the pressure distributions

Pressure profiles of dressed-quarks in the pion and kaon

More speculative observables

What is the trace anomaly contribution to the pion mass?

Elastic J/Ψ production at low W off the pion.

- Need to uniquely determine exclusive process $e + p \rightarrow e' + J/\Psi + \pi^+ + n$ (low $-t$)
- High luminosity ($10^{34} \text{ cm}^{-2} \text{ sec}^{-1}$)
- CM energy $\sim 70 \text{ GeV}$

Can we obtain tomographic snapshots of the pion in the transverse plane? What is the pressure distribution in a pion?

Measurement of DVCS off pion target as defined with Sullivan process.

- Need to uniquely determine exclusive process $e + p \rightarrow e' + \gamma + \pi^+ + n$ (low $-t$)
- High luminosity ($10^{34} \text{ cm}^{-2} \text{ sec}^{-1}$)
- CM energy $\sim 10\text{-}100 \text{ GeV}$

Are transverse momentum distributions universal in pions and protons?

Hadron multiplicities in SIDIS off a pion target as defined with Sullivan process.

- Need to uniquely determine SIDIS off pion $e + p \rightarrow e' + h + X + n$ (low $-t$)
- High luminosity ($10^{34} \text{ cm}^{-2} \text{ sec}^{-1}$)
- $e + p$ and $e + D$ at similar energies desirable
- CM energy $\sim 10\text{-}100 \text{ GeV}$

Impact on EIC Far-Forward Detector Design

Highly Integrated detector system: ~75m

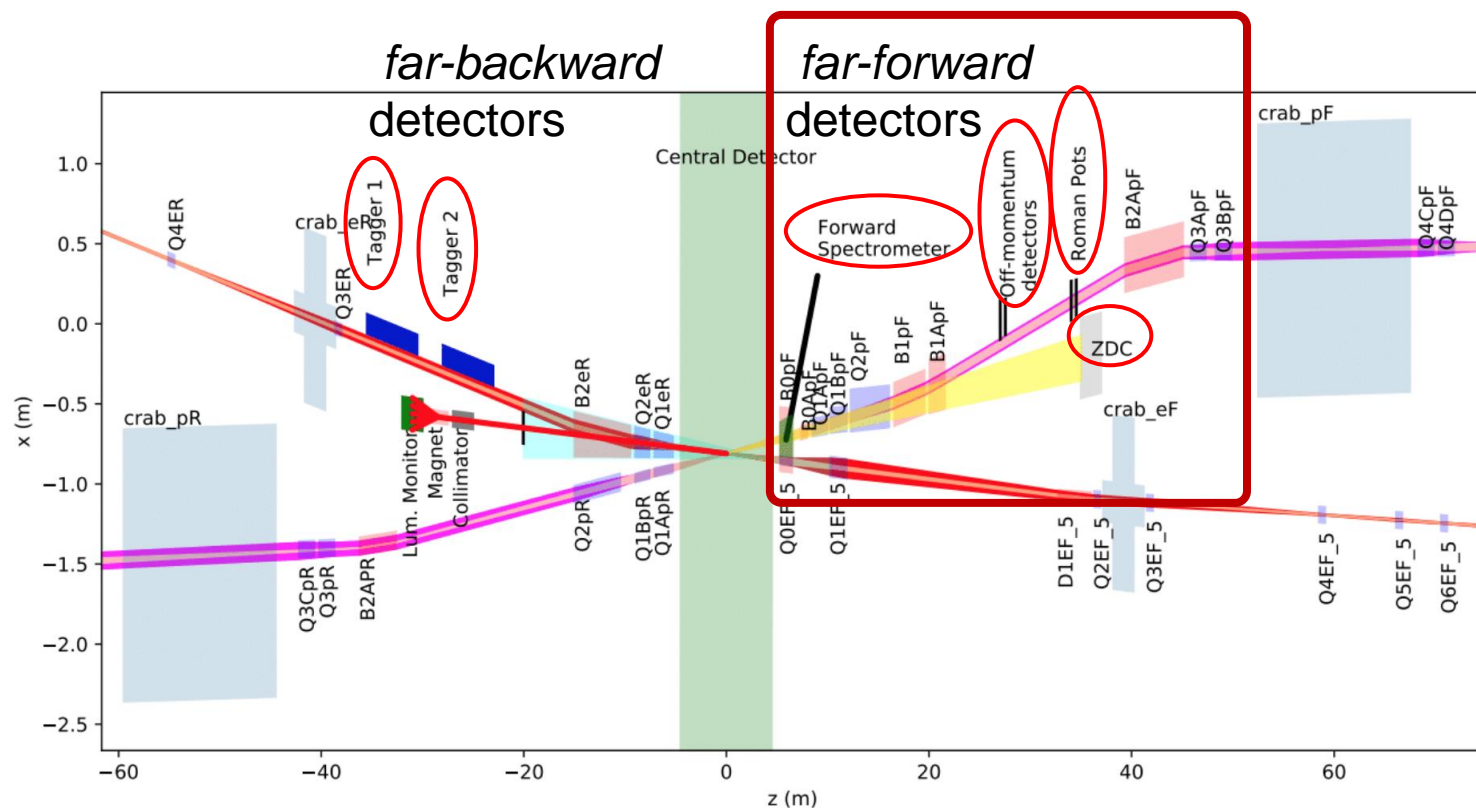
1. Central detector: ~10m

2. Backward electron detection: ~35m

3. Forward hadron spectrometer: ~40m

Lesson learned from HERA – ensure low- Q^2 coverage

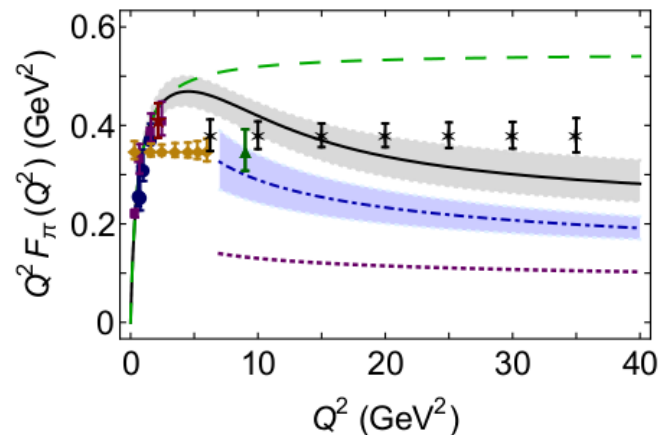
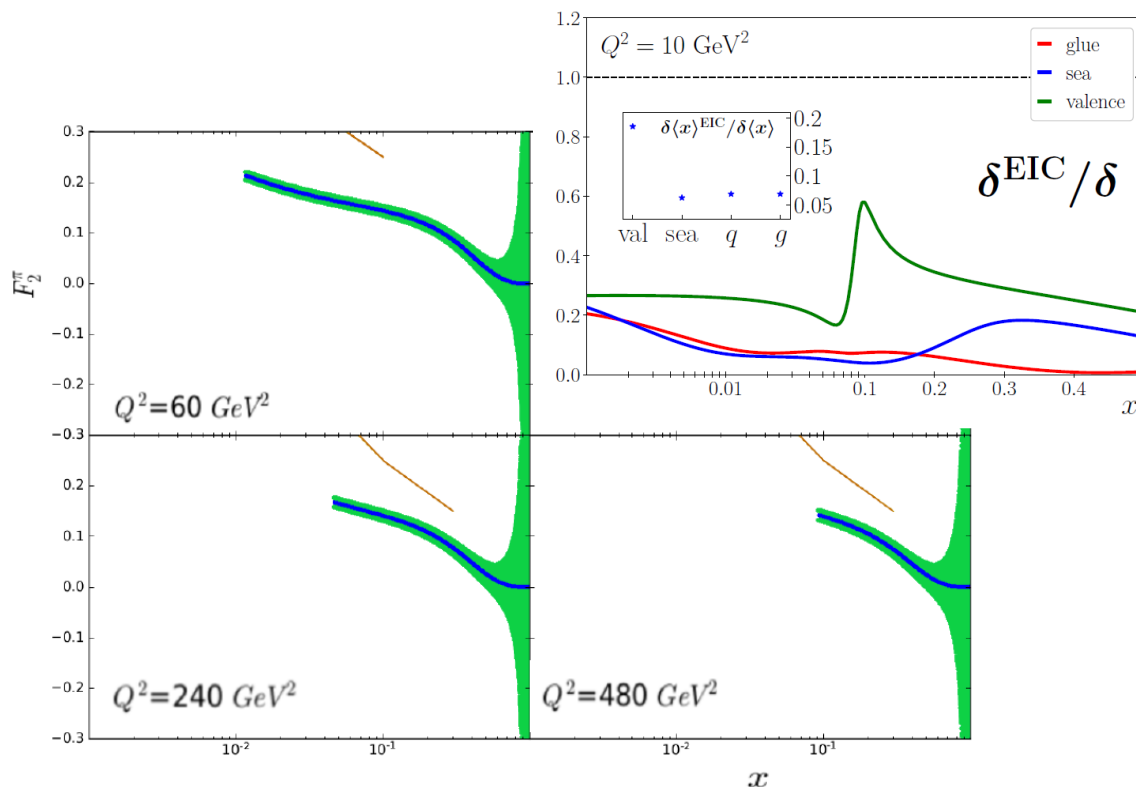
Various stage detector to capture forward-going protons and neutrons, and also decay products (Δ , Λ).



Role of EIC in Meson SF Studies

EIC promises to be the first facility on earth to see scaling violations in a hard exclusive process = pion form factor => locating at the crossover between soft and hard interactions

The unique role of EIC is its access to pion and kaon structure over a versatile large CM energy range, ~ 20 -140 GeV. With its larger CM energy range, the EIC will have the final word on the contributions of gluons in pions and kaons as compared to protons, settle how many gluons persist as viewed with highest resolution, and vastly extend the x and Q^2 range of pion and kaon charts, and meson structure knowledge.



Big Picture Publications based on the WS

- ❑ “*Insights into the Emergence of Mass from Studies of Pion and Kaon Structure.*”, Invited review article for Progress in Particle and Nuclear Physics – submitted in January 2021
- ❑ “*Revealing the structure of light pseudoscalar mesons at the Electron-Ion Collider*” – submission planned to J. Phys. G
- ❑ EIC Yellow Report, Volume 2, Chapters 7 and 8; Volume 3, Chapter 11 – submission planned for early 2021

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Assistance provided by the CFNS

- Aided with promoting the meeting
- Effective support with web page, registration, etc.
- Technical assistance with "carrying" our broadcasts
- Easy to work with the CFNS people ... confident and competent
- All aspects of the teleworkshop proceeded without complication

Thank you!



Craig Roberts
Tanja Horn